PATENT SPECIFICATION

974,774

DRAWINGS ATTACHED

974,774

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COMPLETE SPECIFICATION

Continuous Annealing method and apparatus

We, WESTINGHOUSE ELECTRIC CORPORATION, of Three Gateway Center, Pittsburgh 30, Pennsylvania, United States of America, a corporation organized and existing under the laws of the Commonwealth of Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a continuous annealing method and apparatus, and more particularly to a method and apparatus for the continuous annealing of metal strip, such as low carbon steel tinplate strip.

Present practice in the continuous annealing of steel strip involves the passing of the strip through a thick-walled refractory-lined furnace having radiant heating elements in the form of gas-fired radiant tubes or electric resistance elements, both of high thermal inertia, disposed in vertical arrays between upper and lower pass rolls which direct the strip in multiple loops through the furnace for subjection to the radiant heating effect of such arrays for the period of time necessary to arrive at a desired annealing temperature. Such temperature is usually chosen to be above the recrystallization temperature and below the lower critical or transformation temperature above which the steel strip experiences a dimensional change due to a metallurgical phase change and renders handling of the strip in the furnace in multiple-pass fashion difficult, if not impossible. In order to limit furnace sizes to practical dimensions while affording a reasonable rate of production in the presence of a progressively-diminishing temperature differential between the radiant heating means and the strip as it travels through the furnace, it has been the practice to operate the furnace at a temperature, above the aforementioned critical temperature, hundreds of degrees in excess of the final temperature to which the strip is heated for annealing.

Such practice of employing a furnace at above the critical temperature to heat the metal strip to the annealing temperature exclusively by radiation and at relatively high rates of travel imposes certain limitations with respect to the operating facilities and characteristics which must be provided or accommodated in such method.

For example, a looping tower at the entry to the furnace is employed which is capable of storing a considerable length of strip to enable the following portion of the strip to continue travel through the furnace while its trailing edge at the entrance to the looping tower is temporarily halted for welding to the forward edge of a succeeding strip roll. This prevents overheating of the strip to the excessive furnace temperature, at which temperature, in present practice, the strip is relatively weak and prone to separate easily under influence of the tensioning means, and at which temperature, being above the aforementioned critical temperature, the strip experiences an undesired dimensional change. The large thermal inertia of the furnace affords no opportunity for short-term furnace temperature reduction to serve this end. In furnace annealing lines operating at two thousand feet per minute, for example, and a welding period of thirty seconds, for example, such entry looping tower must be capable of storing a thousand feet of strip, and is necessarily costly, complex, and somewhat difficult to maintain.

By way of another example, the strip must be maintained in tension in order to enable it to properly track the pass rolls which direct its multiple loop path through the furnace. The amount of tension required is a function of strip speed, and since the practice has been to heat the strip to an annealing temperature exclusively by radiation, the transit speed of the strip through such furnace, and hence, the speed of the annealing line have been limited to some extent by the amount of

[*Price 4s. 6d.*]

tension which may be applied to the strip while near or at the annealing temperature.

It is the principal object of the invention to provide a continuous method and apparatus for annealing metal strip, which obviate the need for an entry looping tower, and afford opportunity for increased operating speed of the annealing line and for rapid and precise heat control.

The invention, from one aspect thereof, accordingly resides broadly in a method of continuously annealing metal strip, such as low-carbon steel tinplate strip, in a furnace, characterized in that said furnace is operated at a strip preheating temperature insufficient at all times to heat the strip to its lower critical temperature, and that the strip, upon leaving said furnace, is heated inductively to its final anneal temperature.

The invention, from another aspect thereof, resides in apparatus for annealing travelling metal strip, such as low carbon steel tinplate strip, comprising a furnace for preheating said strip to a temperature at all times below its lower critical temperature, and inductive means disposed at the exit of said furnace for heating the preheated strip to its final anneal temperature.

The invention will becomec more readily apparent from the following description of a preferred embodiment thereof shown, by way of example, in the accompanying drawing, in which:

Fig. 1 is a schematic representation of the novel annealing apparatus for the continuous annealing of metal strip in accordance with the present invention; and

Fig. 2 is a curve showing the temperature of the strip in uninterrupted transit through the apparatus of Fig. 1.

Referring to the drawings, the strip 1 unwinds from the usual coil holder 2 and is fed by positioning rolls 3 past a welding station 4, through a first series of rotary strip gripping means, such as pinch rolls 5 and bridle rolls 6, which are driven by suitable drive means to supply the force unwinding the strip from the holder 2, as is well known in the art, through tension control means 7, and into a furnace 8 of conventional structure, the interior of which includes radiant heating elements 9 operated at a temperature less than the lower critical temperature, i.e. about 1350°F., of the strip material, for example, at about 1250° F, as in annealing 0.01 inch thick, or thinner, low carbon steel tinplate stock. This temperature is one which will afford sufficient strip strength for handling, and will not adversely affect the desired metallurgical properties of the strip, should the latter be subjected to this temperature for a prolonged period of time, as during strip-joining welding or temporary shutdown. Additional strip gripping means 5 and 6, similar to those mentioned above as being disposed before the entrance to the furnace, are also provided near the exit end of the latter, these additional strip gripping means being adapted to be driven to pull, so to speak, the strip through the furnace as it is being fed into it by the first-mentioned strip gripping means at the entrance thereof, as also known in the art. The relative speed between the strip gripping means at the entrance of the furnace and those at the exit end thereof is controlled in known manner by the control means generally indicated at 7.

During travel of the strip through the furnace, the speed of the strip will be such that it becomes heated radiantly to a temperature, e.g. 90° F to 950° F, which is below the final annealing temperature and provides a sufficient differential with respect to the exemplified 1250° F of the radiant heating elements 9 and furnace walls to assure a reasonably rapid radiant heat transfer therebetween.

Finally, the strip is fed through or past induction heating coil means 11 disposed preferably within the furnace 8 and normally energized to raise the temperature of the strip from 950° F, for example, up to its preferred final annealing temperature, which, in the case of steel tinplate material as presently composed, may be within the range of from 1200°F to 1350° F. From the induction coil means 11, the strip may pass through a soak zone (not shown) and/or cooling zones (not shown) as final steps associated with the annealing of the strip.

By means of the method and apparatus of the invention so far described, it is possible to stop the line temporarily and at the same time deenergize the induction heating coil means 11 whereupon the temperature of the strip, although now stopped within the furnace 8, will rise only to the limited furnace temperature and will not be adversely affected by even a prolonged presence in the furnace. This affords opportunity, for example, to weld a new strip roll to the tail end of the first strip without the need for an entry looping tower.

In addition, during normal operation of the line, since the strip is approximately three times stronger in tension at 950° F than it is at 1250° F, in the case of tinplate stock as exemplified, it is apparent that, in accordance with the invention, more tension may be applied to the strip within the furnace up to its final entry into the induction coil means, thereby affording opportunity for increased travel speed of the strip without risk of strip separation within the furnace, which would require a time-consuming re-threading operation. Toward this end, the additional strip gripping means 5, 6 at the exit end of the furnace is disposed ahead of the coil means 11, having regard to the direction of strip travel, so that this gripping means, in conjunction with the gripping means at the entrance of the furnace and the tension control means 7, will

not supply tension to the strip 1 in the region of the higher annealing temperature.

In addition, by inclusion of the induction heating coil means 11 which affords rapid control of its energization and hence, of its heating effect on the strip, the strip line is susceptible to precise and rapid heat control which readily accommodates a relatively high degree of automation. With this point in view, the invention, further provides strip temperature sensing means 12 cooperable with induction coil energization control means 14 to regulate the high frequency power supplied from a high frequency power source 15 to the heating coil means 11. By virtue of such arrangement, the final annealing temperature of the strip may be rapidly, automatically, and accurately controlled.

Thus, in accordance with the broader aspects of the invention, a continuous strip of metal, such as low carbon steel, is annealed by first heating it radiantly within a multi-loop high-thermal-inertia furnace to a temperature less than the final annealing temperature of the strip, thereby affording opportunity for an increase in strip speed through the multiple loops of the furnace by virtue of the increased tensile strength of the strip at the lower-than-final-annealing temperature; followed by heating the radiantly-heated strip inductively by induction heating coil means to bring the strip up to final anneal temperature. To take advantage of the increased strip strength, the influence of the tensioning means on the strip is divorced from the strip as heated to final anneal temperature by the induction heating coil means. By virtue of this basic combination of steps and apparatus wherein the induction heating coil means, rather than the radiant furnace, performs the final heating of the strip, the final temperature desired for annealing is freed from consideration of strip separation and tracking through the vertical multiple-loop path within such furnace, and opens the door to shut-down of the line without danger of overheating the strip, and to experimentation, for example, with annealing temperatures even above the critical or transformation temperatures of the metals, such as low carbon steel, which experience dimensionally-influencing phase changes when heated above these temperatures and render tracking through a long vertical, circuitous path difficult and practically impossible to maintain. Automatic and rapid control of the final annealing temperature of the strip also is afforded by virtue of the susceptibility of the induction heating coil means to such control, in contrast to the high thermal lag inherent in a large radiant furnace.

Where the invention applies to the continuous annealing of the phase-change metals, low carbon tinplate stock as exemplified herein, it is highly desirable, if not imperative, to limit the temperature of the radiant furnace to a value below the critical temperature or temperatures of the metal in order to avoid tracking and strip-separation problems arising from the dimensional changes that take place in the strip when heated above such temperatures.

Where further advantage of the increased strip strength at lower temperatures relative to effecting increase in tracking speed is desired, the furnace temperature may be further reduced to values even below the recrystallization temperature of the metal being annealed, or below 1025° F to 1100° F, for example, for low carbon steel tinplate strip.

WHAT WE CLAIM IS:—

1. A method of continuously annealing metal strip, such as low-carbon steel tinplate strip, in a furnace, characterized in that said furnace is operated at a strip preheating temperature insufficient at all times to heat the strip to its lower critical temperature, and that the strip, upon leaving said furnace, is heated inductively to its final anneal temperature.

2. The method as claimed in claim 1, wherein any tension to which said strip is subjected while passing through said furnace is applied ahead of the inductive heating region, having regard to the direction of strip travel.

3. The method as claimed in claim 1 or 2, wherein said strip is inductively heated only while in travel.

4. The method as claimed in claim 1, 2 or 3, wherein inductive heating of the strip is controlled as a function of the temperature thereof in the inductive heating zone.

5. Apparatus for annealing travelling metal strip, such as low-carbon steel tinplate strip, comprising a furnace for preheating said strip to a temperature at all times below its lower critical temperature, and inductive means disposed at the exit of said furnace for heating the preheated strip to its final anneal temperature.

6. Apparatus as claimed in claim 6, including control means responsive to variations in temperature of the inductively heated strip for varying the level of energization of said inductive means inversely with respect to such temperature variations.

7. Apparatus as claimed in claim 5 or 6, including first and second strip gripping means disposed, respectively, ahead of the entrance to said furnace and at the exit thereof for effecting travel of said strip, and tension control means disposed between said first and second strip gripping means, said second strip gripping means being located ahead of said inductive means with respect to the direction of strip travel, whereby said strip is isolated from tensioning forces in the inductive heating zone.

8. A method for annealing metal strip, such as low-carbon steel tinplate strip, travelling through a furnace of high thermal inertia, sub-

stantially as hereinbefore described with reference to the accompanying drawing.

9. Apparatus for annealing travelling metal strip, substantially as hereinbefore described with reference to, and as illustrated in, the accompanying drawing.

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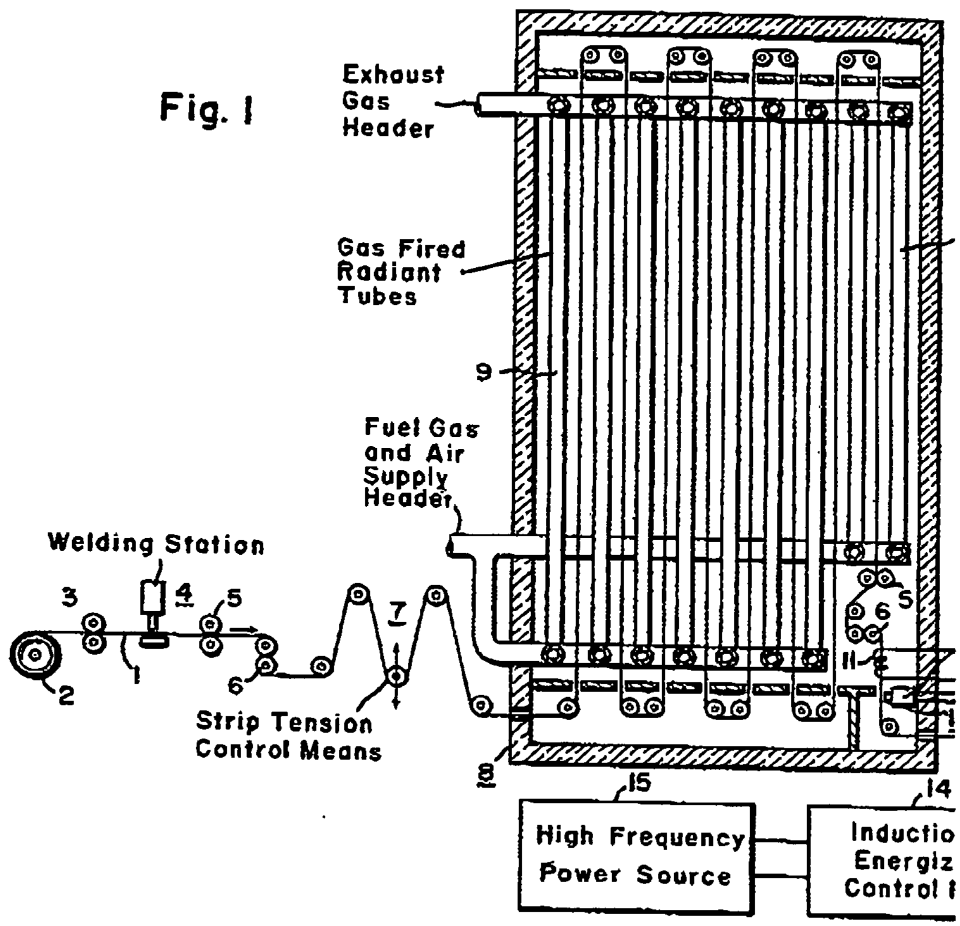
Fig. 1



Exhaust Gas Header
Gas Fired Radiant Tubes
9
Fuel Gas and Air Supply Header
Welding Station
3
4
5
1
2
6
7
Strip Tension Control Means
8
5
6
11
15
14
High Frequency Power Source
Inductio
Energiz
Control

974,774 COMPLETE SPECIFICATION
1 SHEET

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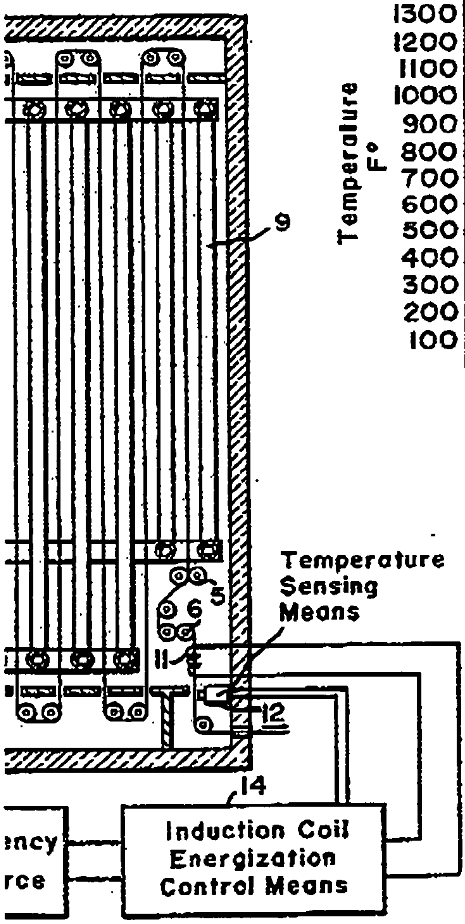


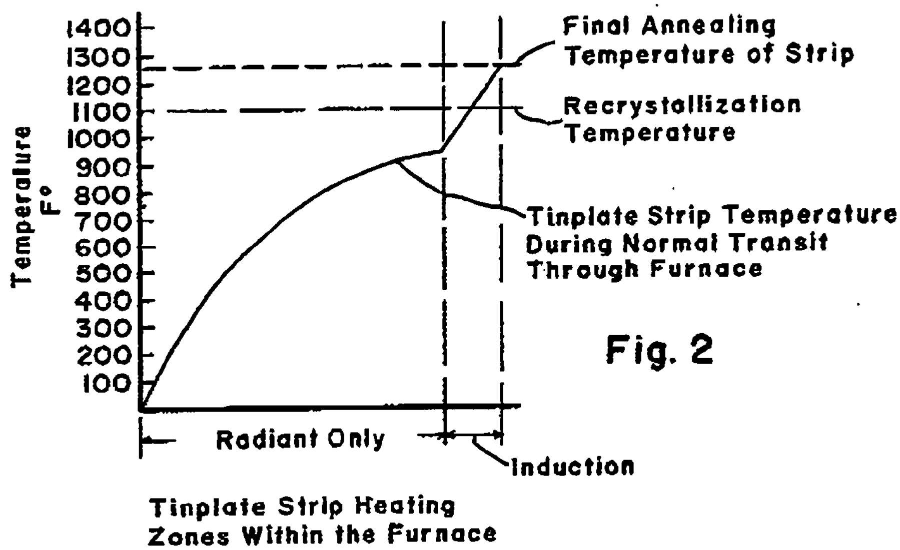
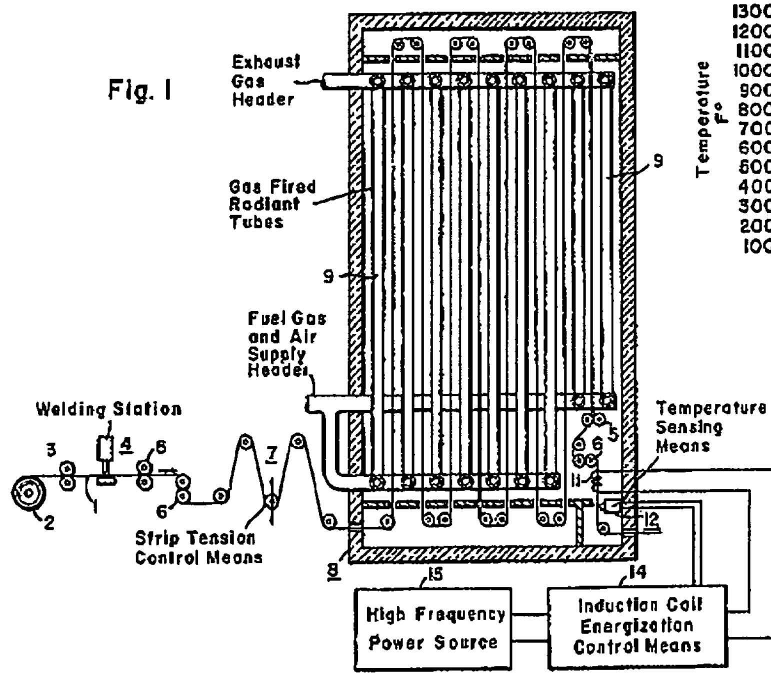


Fig. 2

974,774 COMPLETE SPECIFICATION
1 SHEET

This drawing is a reproduction of the Original on a reduced scale.

Fig. 1



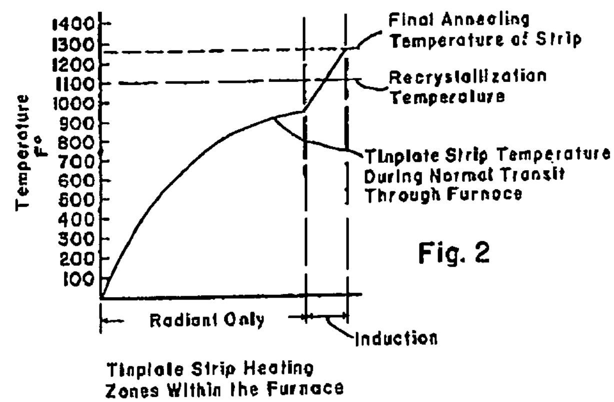


Fig. 2